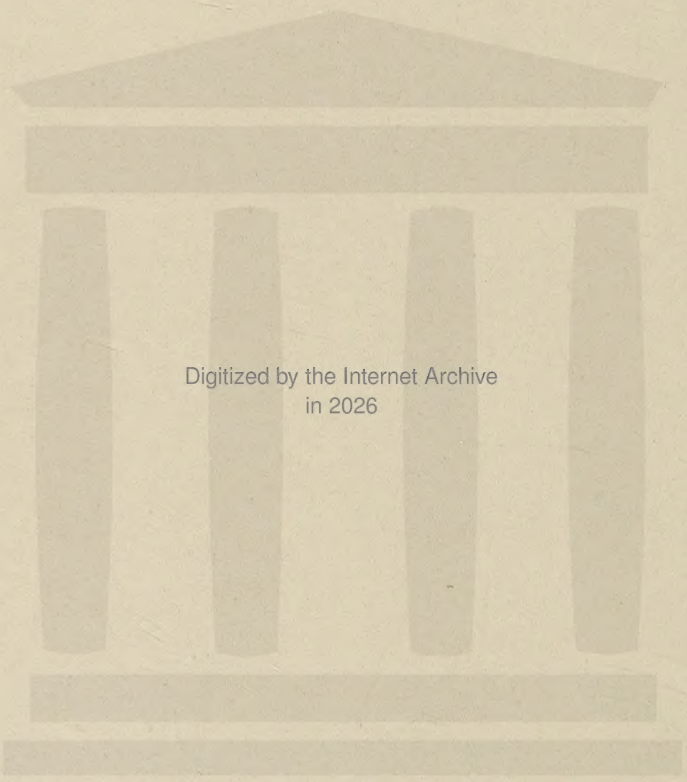
ROWTH RATE
F BROWNS BANK HADDOCK

RESEARCH REPORT 50

FISH AND WILDLIFE SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR



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GROWTH RATE OF BROWNS BANK HADDOCK

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RESEARCH REPORT 50

UNITED STATES
DEPARTMENT OF THE INTERIOR
Fred A. Seaton, *Secretary*
FISH AND WILDLIFE SERVICE
Arnie J. Suomela, *Commissioner*

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ABSTRACT

A study of the growth rate of Browns Bank haddock, by a method of back-calculations from haddock scales taken from fish that ranged in age from 4 to more than 10 years old, reveals that the growth rate is considerably slower than that for haddock on Georges Bank, but faster than that previously determined for haddock from Nova Scotia.

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GROWTH RATE OF BROWNS BANK HADDOCK

Browns Bank, conveniently described as bounded by the fifty-fathom isobath, is located about 25 nautical miles south of Cape Sable, Nova Scotia, with its center about 42°35′ north, 65°50′ west. Roughly, 1,400 square miles are enclosed within the 50 fathom curve. It is isolated from Georges Bank to the southwest by depths of 100 fathoms and more in the Fundian Channel. To the northeast similar depths in the Scotian Gulf separate the area from the Western Bank and the more remote Grand Banks. Between Browns and the Scotian Gulf there are smaller banks of little importance to the fishery: Roseway, La Have, Little La Have, and Sambro. Although it seems likely that the haddock of these smaller banks are similar to those of Browns Bank, this study is confined to Browns Bank proper.

Despite the proximity of Browns Bank to the southwestern tip of Nova Scotia, it is little fished by Canadians, and perhaps because of the long distance separating it from the more northeasterly cod fishing grounds favored by the European fishermen, it is virtually untouched by European fleets.

It is, however, an important contributor to United States landings of haddock as may be seen from the following table compiled from published and unpublished sources:

Year	Haddock landings from Browns Bank area (in millions of lbs., as landed)	Percent of total U. S. haddock landings
1947	14.0	10.1
1948	15.0	11.5
1949	12.3	11.1
1950	15.4	11.7
1951	12.8	9.9
1952	21.7	16.0
1953	15.7	13.3
1954	27.5	20.3
1955	22.2	18.8

These data are the more significant when it is considered that nearly all fishing in the Browns area by the United States fleet is done in the first few months of the year, with little or none at other times. During the fishing season the bank is not fished uniformly, for effort is concentrated on the eastern and western ends (Schuck 1952).

The haddock of the area have long been recognized as "different" from other haddock. Dealers and handlers at the Boston Fish Pier, where the overwhelming majority of United States landings are processed, can identify at a glance haddock from Browns Bank, although they may be hard pressed to define the distinguishing characteristics. Schuck and Arnold (1951) compared Browns Bank haddock for age composition and length frequency with Georges Bank fish

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caught at the same time and found striking differences; tagging and meristic studies also indicate isolation of the Browns fish (Needler 1930, Clark and Vladykov [1]).

For many years data have been collected on all haddock landings at the Boston Fish Pier, but only those data pertaining to Georges Bank have been routinely analyzed. The objective of this paper is to present the results of a study of some of the collected information for the clues it may yield to an understanding of the population dynamics of the haddock stock of Browns Bank.

All persons collecting haddock scale samples were instructed to remove scales from the part of the fish that lies between the second and third dorsal fins and below the lateral line, and it is reasonable to assume that most of the scales came from this area.

Only samples from haddock captured in the first quarter of the year were used in establishing the fish length-scale length relationship and in back-calculation. (One noncommercial sample was from lat. 42°55′ N., long. 64°55′ W., a few miles outside the selected area, and was collected in the first half of April, but the scales were from fish of very small size and it was felt that any damage done by making this slight exception would be more than offset by the value derived from the use of such small fish.) The reasons for this are two. Empirically speaking this is the period when the vast majority of haddock are caught on Browns Bank and from which samples are available. In addition, this is the time of the year when growth has ceased or nearly ceased. The rigid geographical and time limits serve to eliminate the possibility of contamination by other stocks and the fluctuations in scale length caused by the inception of summer growth.

[1] Manuscript.

Back-calculation method

In order that collections of scale samples from commercial landings might be used to fullest advantage it was decided to explore the possibility of using a back-calculation method for determining the growth rate. Briefly, this consists of establishing a fish length-scale length relation for the stock under investigation and calculating the length of the individual fish from the length of its scale at the completion of each year's growth as evidenced by an annual mark or check. While this method may not establish a reliable length for the individual a mean of the calculated lengths of many fish of the same age has been shown to give a good measure of the average length at a particular age (Van Oosten 1929).

Only those commercial samples which were from fish captured within relatively narrow geographical limits were used. For this purpose the bank was considered a rectangle enclosed within the following latitude and longitude coordinates:

Latitude	*Longitude*
42°20′ N.	66°30′ W.
43° 0′ N.	66°30′ W.
43° 0′ N.	65° 0′ W.
42°20′ N.	65° 0′ W.

As the commercial samples were deficient in smaller fish of unmarked

able sizes, collections made on the *Albatross III* or by technicians on commercial trips were also included. Where scales and measurements from extremely large fish were available in the special collections, they were used. Altogether, 234 individual measurements of fish ranging from 130 mm. to 640 mm. supplemented the 613 routine pier samples.

Growth rate

Scale samples from commercial trips and special collections were available from 847 fish that met the criterion for location and date of capture. These had been collected in the years 1942–54, inclusive. A 13-year span should tend to eliminate the possible biasing effect on growth rates of atypical year-classes or unusual hydrographic conditions. The collections for any one year of fishing or year-class of fish were insufficient in number for back-calculation.

The scales were impressed in cellulose acetate slides by means of heat and pressure (Arnold 1951), and the impressions measured to the nearest tenth millimeter on the anterior radius from the focus to the farthest point on the edge. Spot checks showed that the size of the impression of the scale does not vary measurably from the size of the scale throughout the range used. When available, three scales chosen at random from each scale sample were averaged, but regenerated or obviously deformed scales were rejected.

The image of each impression was projected by a commercial microprojector onto a measuring scale calculated to read directly in tenths of a millimeter at the magnification used, about 25X. The effect of spherical abberation of the lens system was found to be of the order of 5 percent at the edge of the field and much less progressively toward the center. Since measurements were made mainly near the center of the field, any error introduced can safely be ignored.

Figure 1 shows the fish length-scale length measurements plotted with the line of best fit. The line chosen was determined by grouping the scale measurements by 0.3 millimeter units and averaging the fish-length measurements for each increment. This method varies from the one usually used in that the scale length is considered the independent variable, but recent examination of the problem shows it to be desirable (Whitney and Carlander, 1956).

A straight-line relation was found from the smallest scale length up to about 3.5 millimeter scale length or about 510-mm. fish length. The formula for this line is $Y=50.0+134.3X$, where Y is fish length in mm. and X is scale length in mm. Beyond the 3.5 millimeter scale length the line was fitted by eye to the 0.3 mm. increment averages.

The form of the line is worthy of comment. Many workers, e. g., Perlmutter (1949), have noted curved relationships or relationships curved in part, but all or nearly all have chosen some compromise straight line on which to base calculations. Thompson (1923) found for North Sea haddock a proportional relation which yielded a straight-line fit. Among those who

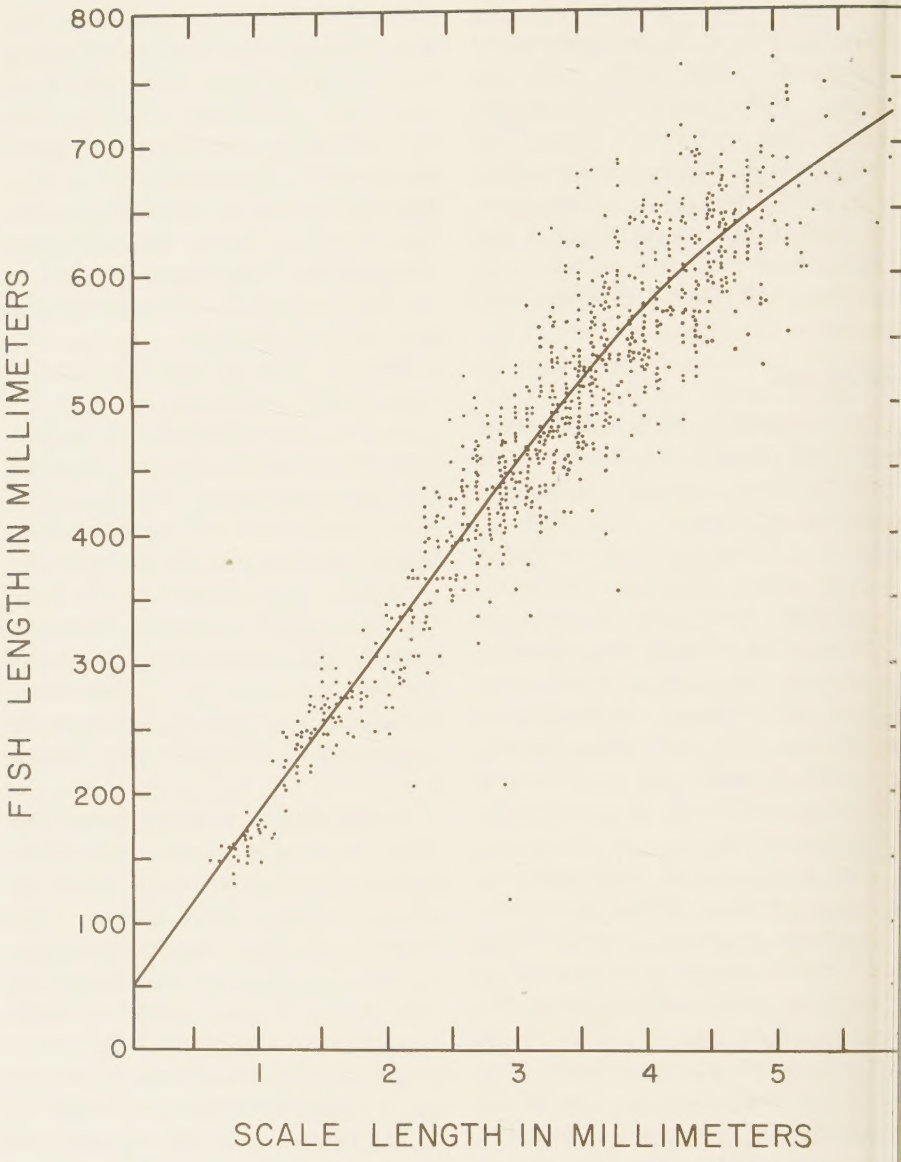

Figure 1.—Fish length versus scale length for Browns Bank haddock.

have noted the existence of a curvilinear relation, it has most often been found that the scale growth decreased as the fish became larger. In this case, however, there is strong evidence that the scale growth increases with increasing fish-size after a certain critical size is reached. A similar study of Western Bank haddock [2] has demonstrated the same phenomenon.

No explanation for this seem readily available although there

[2] Unpublished.

a possibility of association with sexual maturity. Van Oosten (1929) discusses the scale length-fish length relation and cites the findings of various workers.

Using this sort of relationship in back-calculations imposes certain difficulties. Common practice has been to employ a simple proportionality equation of the form

$$\frac{s_i}{S}=\frac{l_i}{L}$$

where L is the length of the fish at capture and S its scale length; l_i and s_i being similar dimensions at the time of completion of annulus i. In some cases, including Georges Bank haddock, it has been necessary to include a term to correct for the line not originating at zero for the presumptive reason that the fish does not form its scales until after it has attained a certain size. Schuck (1949) discusses the problem and describes an ingenious mechanical device for handling such equations with or without the correcting term.

Because this equation is useful only when a straight regression line exists or can be assumed, it cannot be used here. The first alternative, which is simply to scale off fish lengths from measured scale lengths, falls short for two reasons. First, it ignores the different individual growth rates of different fish; second, it derives an over-all length at capture different from that actually attained.

G. A. Rounsefell [3] proposed the use of a nomograph, shown in figure 2. Here the fish length-scale length relation is presented with two ordinate lines, the one with italic numerals and legend being longer than the base line. The longer ordinate line was engraved on a transparent plastic strip which pivots at the origin. When this strip is rotated it effectively increases or decreases the value of the scale length in relation to the fish length. Thus the appropriate total scale length for each fish used in back-calculation may be brought into vertical relation to the point on the regression line corresponding to the fish length at capture. For example, if a selected scale is 5 millimeters long and the fish from which it came was 58 centimeters in length, the variable ordinate scale is brought into the position shown in figure 2. With this relation established for the individual fish, body lengths corresponding to scale lengths at the completion of each annulus can be read from the regression line in correct proportion for that individual. In the example cited, the scale length at the completion of the fifth annulus was 3.0 millimeters. For this value the length of the fish is scaled off at 35 cm.

Scale impressions from commercial samples meeting requirements for time and place of capture were selected for symmetry and typical or normal appearance. These were projected onto a blank white card and the location of the focus and the anterior extremity of each annulus marked on the card. Then with a specially constructed rule designed to read directly in tenths of a millimeter at the chosen magnification, the scale length at the completion

[3] Personal communication.

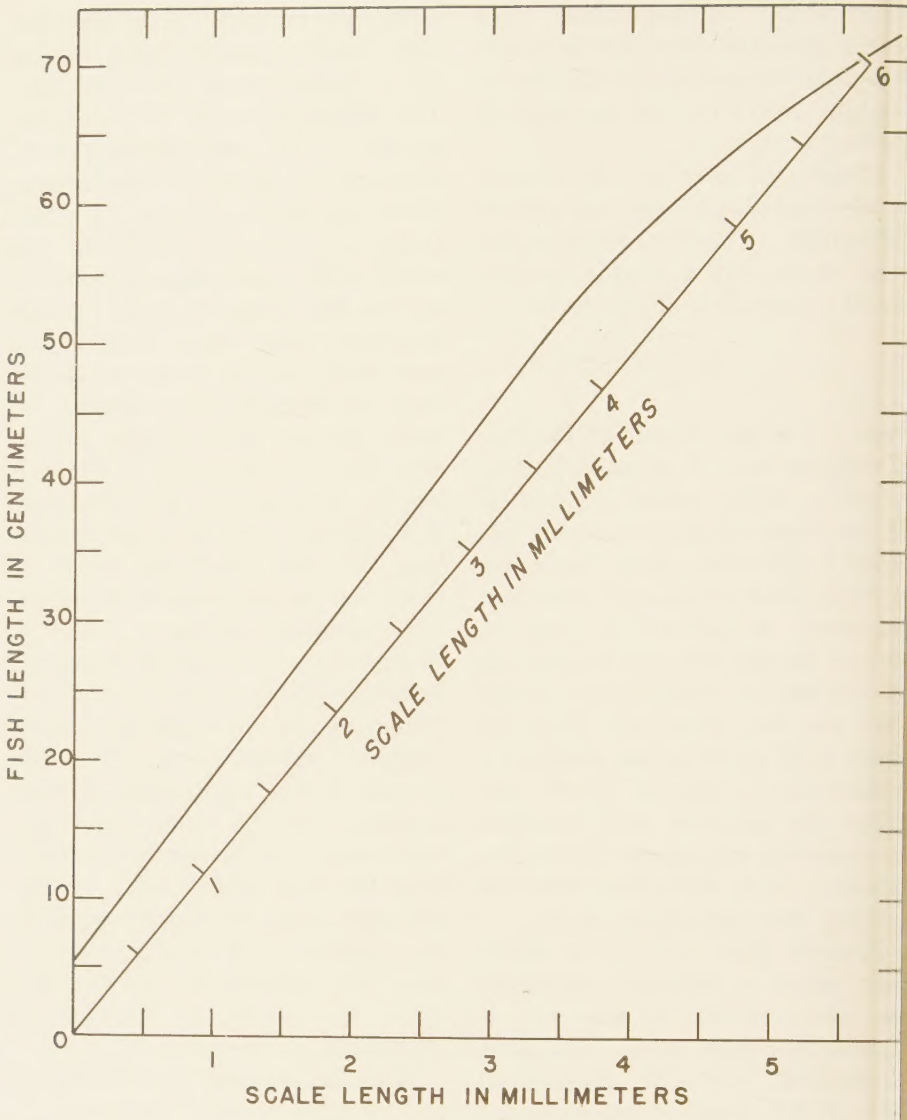

Figure 2.—Nomograph used in calculation.

of each annulus was noted at each mark to the nearest tenth millimeter.

By means of the nomograph described, the length of the fish at the completion of each year of growth was calculated.

A sample of about 150 fish fron the 847 above was used in back calculation. Tests of the standar error showed this number to b adequate; there is only one chanc in one hundred that the mean deviate as much as half a cent

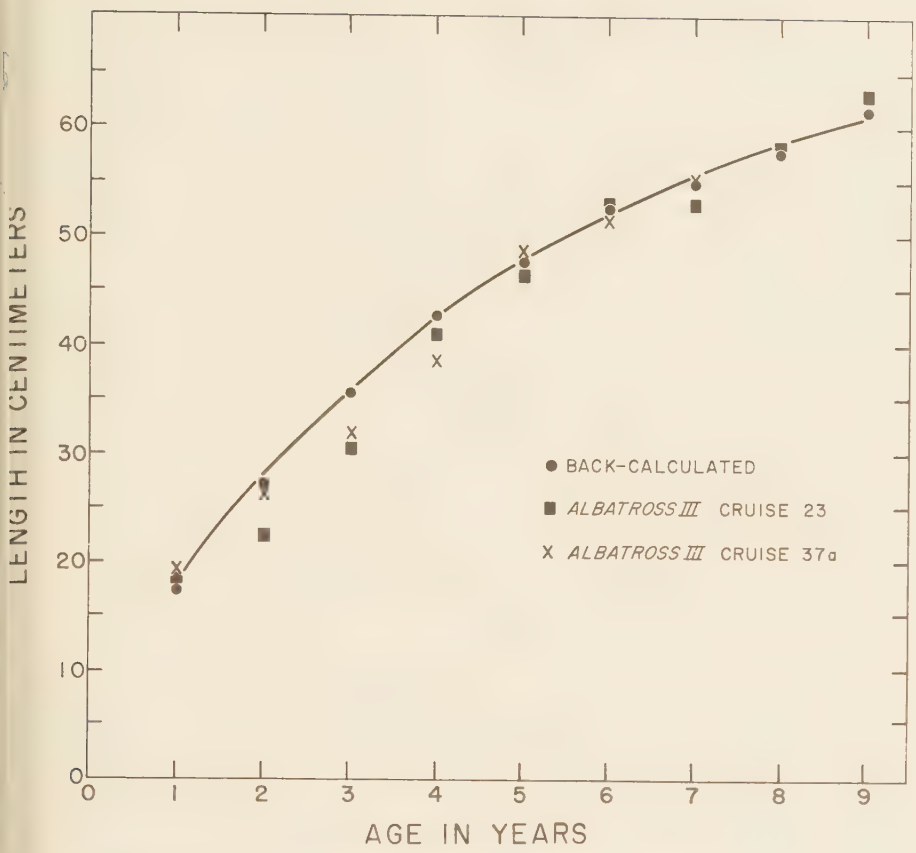

Figure 3.—Back-calculated growth rate for haddock from Browns Bank.

neter from the true average growth. (See tables 1–8.)

The length-at-age points thus determined are:

Age in years	*Length in millimeters*
1	175
2	272
3	356
4	427
5	476
6	523
7	546
8	576
9	613

These are shown in figure 3 with a fitted growth curve whose equation is $l_t = 72.11\ [1 - e^{-.1998\ (t\ +\ .45)}]$.

Additional points have been plotted from fish captured on Browns Bank with a very small-meshed net in two successive years (Schuck and Arnold, 1951). The only points from these research collections differing markedly from the growth curve here presented are those of 2 year classes, showing the first year as 2- and 3-year-old fish and the next year as 3- and 4-year-olds. Schuck and Arnold contend that these year classes were below normal in attained size, and comparison of their growth curves with our growth curve derived from several year classes bears out this hypothesis.

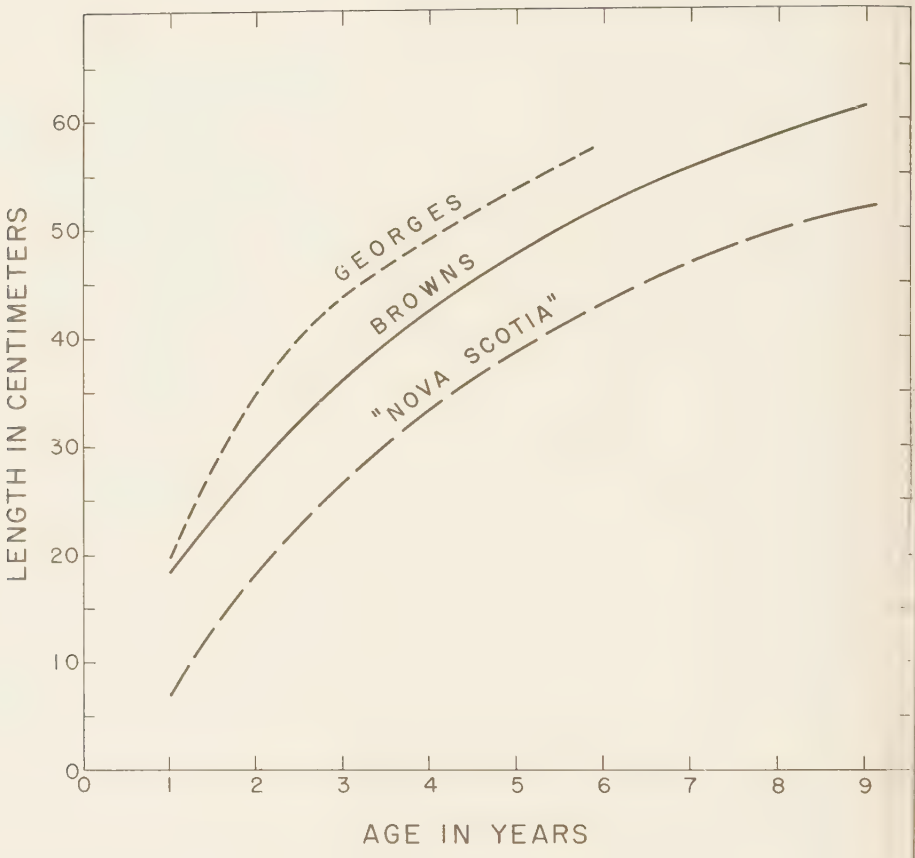

Figure 4.—Comparison of haddock growth rates.

Figure 4 shows the Browns growth curve compared with one for Georges Bank (Graham 1952) and one given by Thompson (1939) for Nova Scotia. (Although Thompson does not mention the source of his samples, we infer that they were from Banquereau exclusively and are, therefore, not necessarily representative of the whole Nova Scotia area.)

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TABLE 1.—*Lengths back-calculated from scales of haddock 10 or more years old*

[Length in millimeters at completion of annulus]

Haddock	Age in years											
	1	2	3	4	5	6	7	8	9	10	11	12
Lengths back-calculated from haddock scales.	165	271	363	432	467	491	515	535	547	576	594	600
	159	208	260	320	359	389	437	466	487	506	-------	-------
	236	319	385	484	554	595	606	668	706	717	-------	-------
	218	340	430	522	555	584	594	612	647	672	-------	-------
	177	291	362	417	459	515	543	583	618	636	-------	-------
	168	290	410	470	576	550	565	604	645	662	-------	-------
	234	306	397	452	523	575	606	638	668	694	-------	-------
	156	269	349	460	512	535	516	607	624	640	-------	-------
	170	275	366	411	470	528	554	574	594	612	-------	-------
	183	250	355	465	498	563	584	606	626	644	-------	-------
	160	244	299	355	437	480	512	553	586	602	-------	-------
Mean	183	278	361	435	492	528	548	586	613	-------	-------	-------
$\sigma\bar{x}$	9.1	11.1	14.5	17.4	18.9	17.8	18.4	16.4	17.8	-------	-------	-------

TABLE 2.—*Lengths back-calculated from scales of haddock 9 years old*

[Length in millimeters at completion of annulus]

Haddock	Age in years								
	1	2	3	4	5	6	7	8	9
Lengths back-calculated from haddock scales.	145	170	251	292	385	427	467	505	538
	180	310	426	521	567	599	612	630	640
	196	300	400	460	540	586	600	620	636
	150	194	281	368	410	454	490	543	591
	199	280	348	388	442	520	555	575	585
	132	230	297	353	392	435	459	485	512
	189	309	429	516	505	578	592	617	625
	145	213	270	352	408	450	505	530	548
	140	215	350	395	440	500	540	570	604
Mean	164	247	339	405	454	505	535	564	-------
$\sigma\bar{x}$	8.9	17.8	22.7	26.0	22.3	22.8	19.4	17.4	-------

TABLE 3.—*Lengths back-calculated from scales of haddock 8 years old*

[Length in millimeters at completion of annulus]

Haddock	Age in years							
	1	2	3	4	5	6	7	8
Lengths back-calculated from haddock scales.	209	336	410	498	555	582	604	623
	170	243	304	337	388	433	480	503
	144	252	321	371	392	440	463	510
	245	370	424	466	508	540	556	586
	182	238	358	438	536	572	582	598
	155	230	275	380	453	528	547	557
	161	218	316	361	440	509	545	563
	163	251	295	367	422	452	480	533
	148	270	343	418	478	515	493	560
	193	236	306	403	492	530	566	578
	184	265	318	398	465	517	550	565
	167	250	325	382	464	532	556	571
	176	273	387	450	498	572	590	611
	130	204	300	360	409	469	527	557
	200	304	394	480	546	600	620	639
	188	275	382	487	520	600	624	645
	198	293	365	424	471	531	560	594
Mean	177	265	343	413	473	525	550	-----
$\sigma_{\bar{x}}$	6.7	10.2	10.0	12.1	12.5	12.5	11.5	-----

TABLE 4.—*Lengths back-calculated from scales of haddock 7 years old*

[Length in millimeters at completion of annulus]

Haddock	Age in years						
	1	2	3	4	5	6	7
Lengths back-calculated from haddock scales.	188	318	379	470	519	541	[illegible]
	180	244	310	407	504	585	64
	135	250	300	350	400	450	4[illegible]
	155	200	343	438	548	592	6[illegible]
	186	298	365	405	461	516	5[illegible]
	183	268	311	356	398	441	4[illegible]
	177	258	333	384	409	434	44
	178	235	306	351	432	475	5[illegible]
	164	267	325	349	404	462	4[illegible]
	180	250	307	350	395	422	4[illegible]
	148	190	275	389	423	445	5[illegible]
	177	332	431	478	527	568	[illegible]
	170	255	327	398	433	483	5[illegible]
	272	369	440	526	585	624	6[illegible]
	155	283	364	423	481	528	5[illegible]
	210	286	350	438	490	529	5[illegible]
	236	369	450	562	610	638	6[illegible]
	209	340	440	500	547	584	6[illegible]
	148	194	282	356	443	470	5[illegible]
	197	305	400	460	522	557	5[illegible]
	165	265	381	496	562	589	6[illegible]
	149	264	455	557	593	624	6[illegible]
	163	250	333	420	452	493	5[illegible]
	165	273	368	401	437	473	4[illegible]
	170	291	369	443	488	531	5[illegible]
	144	198	291	359	397	465	5[illegible]
	197	270	329	389	448	493	5[illegible]
	168	250	301	360	450	525	5[illegible]
	143	298	420	495	537	508	5[illegible]
	158	260	344	400	391	570	[illegible]
	134	239	333	403	473	520	[illegible]
Mean	174	270	354	423	476	521	[illegible]
$\sigma_{\bar{x}}$	6.8	8.1	9.4	11.2	11.6	10.9	[illegible]

TABLE 5.—*Length back-calculated from scales of haddock 6 years old*

[Length in millimeters at completion of annulus]

Haddock	Age in years					
	1	2	3	4	5	6
engths back-calculated from haddock scales	218	352	487	518	618	652
	210	300	371	471	428	557
	166	270	385	462	500	523
	133	193	250	356	450	528
	194	304	385	463	510	548
	126	204	290	377	444	485
	152	218	334	422	454	488
	160	258	340	395	439	506
	185	248	322	429	507	542
	183	290	363	471	519	545
	154	204	301	393	469	505
	193	292	404	482	509	562
	214	296	344	411	476	546
	204	319	412	527	567	621
	189	274	359	400	440	481
	147	229	362	469	519	553
	134	280	362	460	537	570
	163	222	302	393	463	506
	155	288	390	480	533	565
	188	293	399	473	530	560
	156	249	328	406	509	560
	198	280	360	456	509	541
	145	240	288	359	441	501
	177	294	346	378	453	494
	121	204	299	380	414	435
	183	241	285	359	402	444
	182	240	311	398	427	500
	140	234	300	376	416	478
	175	269	324	393	403	461
	203	285	336	385	435	469
	160	244	299	381	424	449
	153	255	312	356	413	455
	159	241	311	380	448	488
	144	204	330	361	398	452
	160	288	355	410	507	551
Mean	169	260	341	418	472	----------
$\sigma_{\bar{x}}$	4.4	6.4	7.8	8.2	8.9	----------

TABLE 6.—*Lengths back-calculated from scales of haddock 5 years old*

[Length in millimeters at completion of annulus]

Haddock	Age in years				
	1	2	3	4	5
Lengths back-calculated from haddock scales	210	329	409	500	53
	189	317	349	447	53
	179	282	345	474	51
	231	370	440	508	54
	312	404	515	543	56
	238	361	454	529	57
	213	328	429	477	52
	179	320	392	492	54
	167	250	348	400	43
	156	261	329	435	50
	155	323	403	465	53
	139	267	354	453	52
	193	353	409	480	50
	137	226	314	427	53
	140	260	384	458	50
	150	266	383	485	52
	153	247	339	429	49
	136	260	360	475	51
	154	344	419	477	52
	174	264	327	427	47
	194	327	400	424	47
	150	239	290	389	45
	172	294	379	453	49
	140	241	305	409	45
	150	242	294	410	46
	183	270	343	449	50
	153	225	297	390	43
	175	238	326	401	42
	166	258	320	370	39
Mean	175	288	367	451	
$\sigma_{\bar{x}}$	7.1	9.0	10.0	8.0	

TABLE 7.—*Lengths back-calculated from scales of haddock 4 years old*

[Length in millimeters at completion of annulus]

Haddock	Age in years			
	1	2	3	4
Lengths back-calculated from haddock scales	196	275	406	5
	164	255	353	4
	195	300	447	5
	191	350	484	4
	205	319	429	5
	149	264	361	4
	171	264	383	5
	200	298	381	4
	194	312	420	4
	196	276	397	4
	177	252	391	4
	159	270	352	4
	170	265	361	4
	174	263	325	3
	156	259	363	4
Mean	180	281	390	
$\sigma_{\bar{x}}$	4.4	7.3	10.8	1

TABLE 8.—*Summary of lengths back-calculated from scales of haddock 4 to 10+ years old*

[Length in millimeters at completion of annulus]

Haddock	Age in years								
	1	2	3	4	5	6	7	8	9
From age 10+	183	278	361	435	492	528	548	586	613
From age 9	164	247	339	405	454	505	535	564	------
From age 8	177	265	343	413	473	525	550	------	------
From age 7	174	270	354	423	476	521	------	------	------
From age 6	169	260	341	418	472	------	------	------	------
From age 5	175	288	367	451	------	------	------	------	------
From age 4	180	281	390	------	------	------	------	------	------
Mean	175	272	356	427	476	523	546	576	613
$\sigma\hat{x}$	2.5	3.7	3.6	5.0	6.0	6.3	8.3	11.9	17.8

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